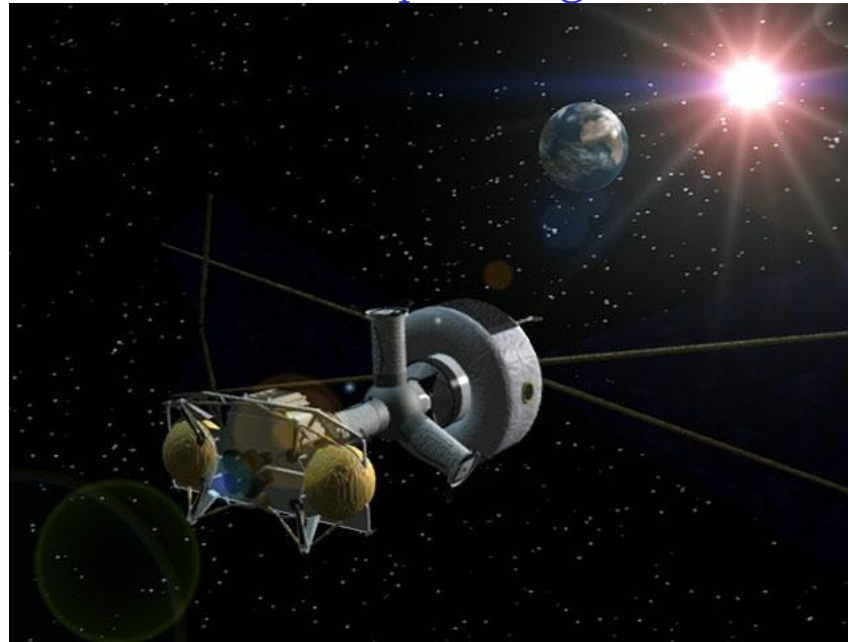


Human Servicing Operations Beyond LEO: “Gateways” and Precursor Concepts

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Early concept for TransHab-based inflatable "Gateway" habitation facility approaching the Earth-Moon $L_{1,2}$ venue to demonstrate capabilities for long-duration human operations in deep space. Source: NASA Decade Planning Team (DPT) and John Frassanito & Associates (2000)

Overview

Over the past decade, a handful of concepts have been assessed that would permit human operations, including on-orbit assembly and upgrade, beyond LEO.

In this presentation, I will summarize two that were developed under very different ground rules, although both take advantage of the attractive characteristics of Sun-Earth-Moon libration points as transfer sites.

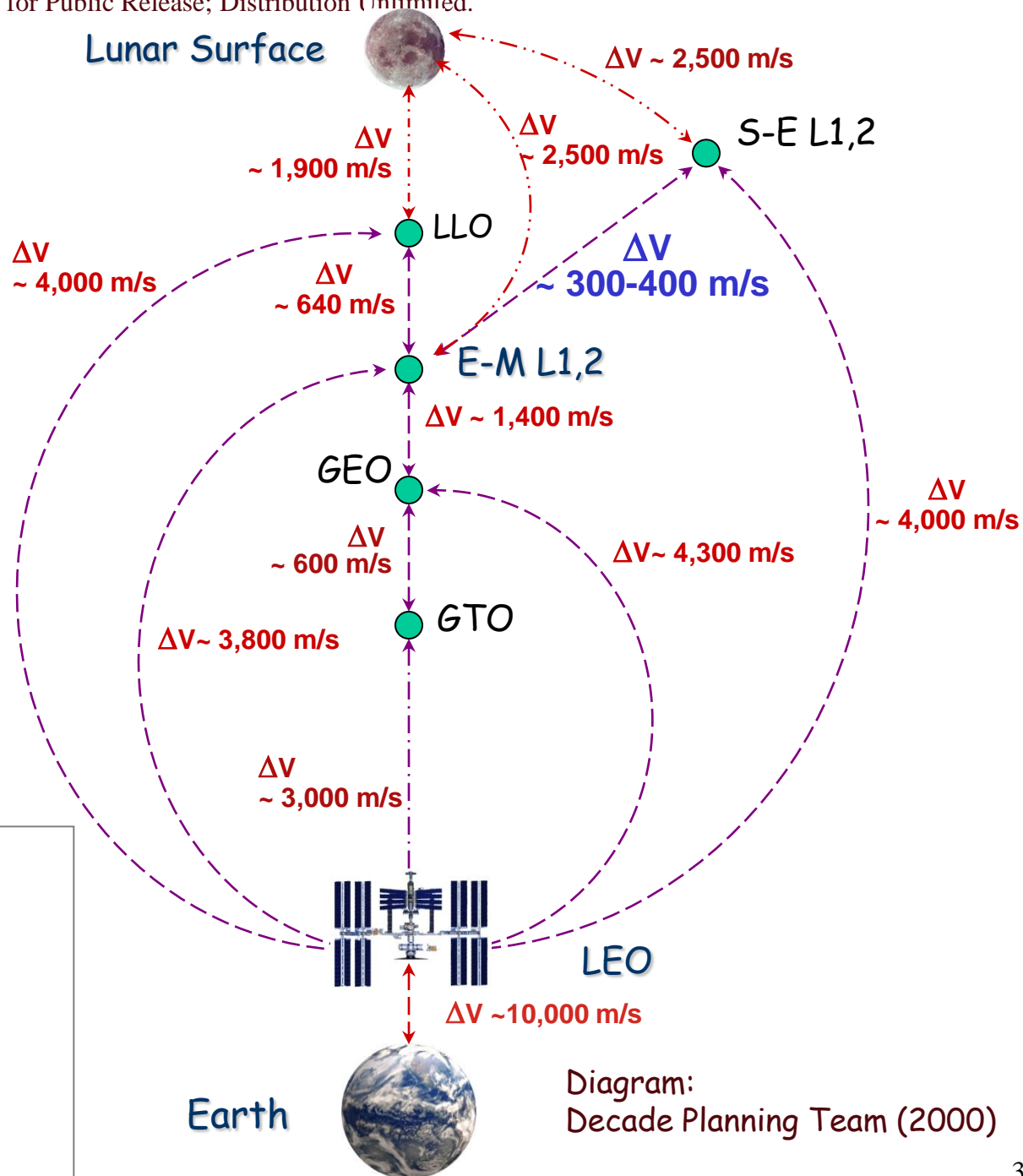
An Early Orion-based Servicing System: a proposed 2008 design to use elements of the Constellation Program (or equivalent) with the explicit goal of the earliest, least-expensive human servicing mission beyond LEO.

The "Gateway" Human Operations Facility: a post-ISS single-launch (via heavy lift) *TransHab*-based module intended to achieve multiple major goals: (1) build on ISS experience; (2) demonstrate capabilities necessary for long-duration human space flight; (3) support astronaut/robot lunar surface operations; and (4) manage/assemble/upgrade major on-orbit facilities, including depot systems and large optical systems.

Ref: <http://futureinspaceoperations.com>

Proposed HSF capabilities offer opportunities for satellite servicing throughout the Earth-Moon system.

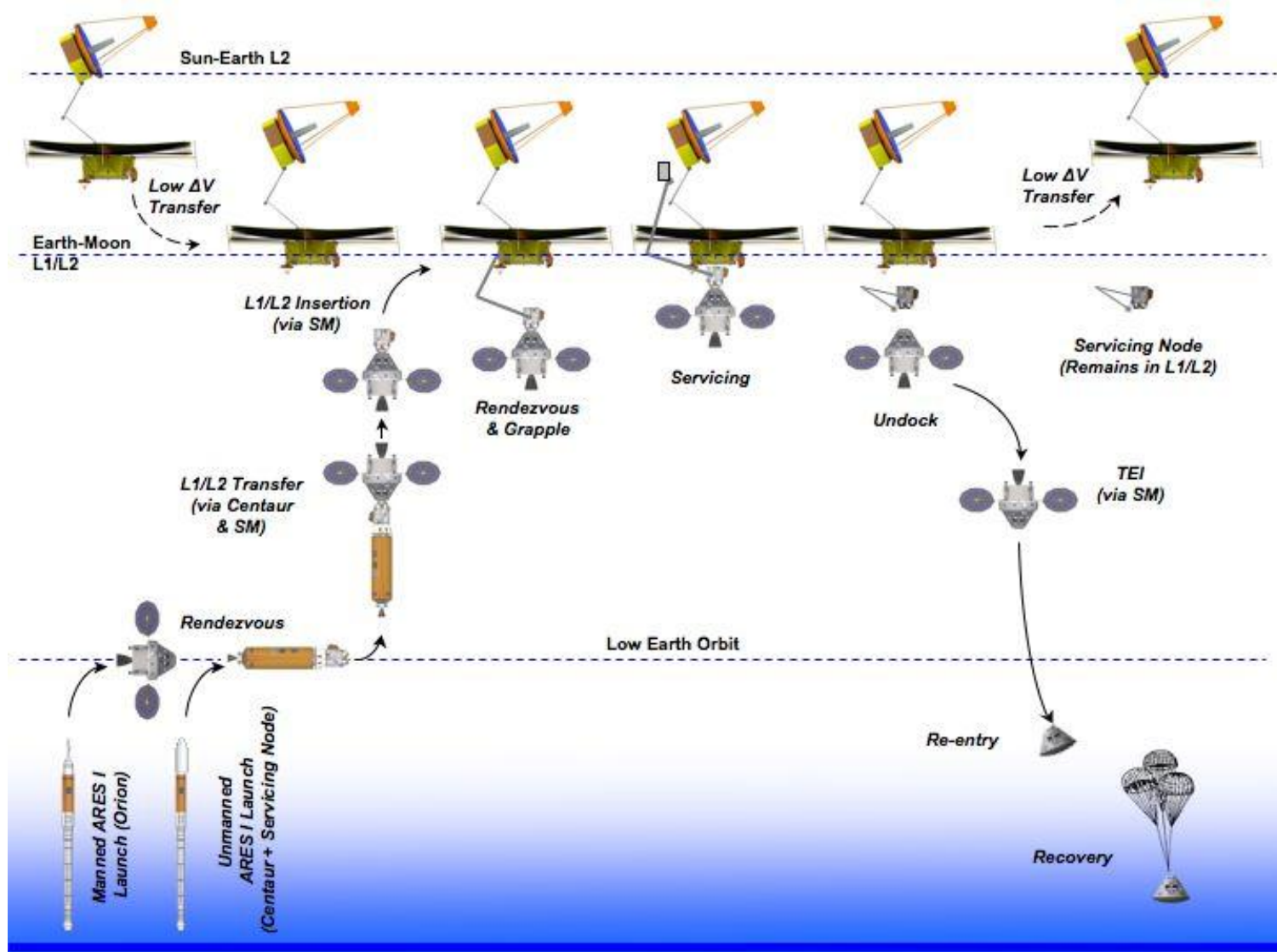
Note the very modest velocity transfer between the Sun-Earth libration points, where we want to put out large telescopes, and the Earth-Moon libration points.
Could we create a servicing "job site" at the Earth-Moon libration points?



LTO Lunar Transfer Orbit
 LLO Low Lunar Orbit
 SE L2 Sun-Earth Libration Point L2
 EM L1 Earth-Moon Libration Point L1
 GEO Geostationary Orbit
 GTO GEO Transfer Orbit
 LEO Low Earth Orbit
 Low-T Low-thrust
 High-T High-thrust

Diagram:
 Decade Planning Team (2000)

Minimum Human Servicing Mission Beyond LEO: Dual-Launch of Orion to E-M $L_{1,2}$

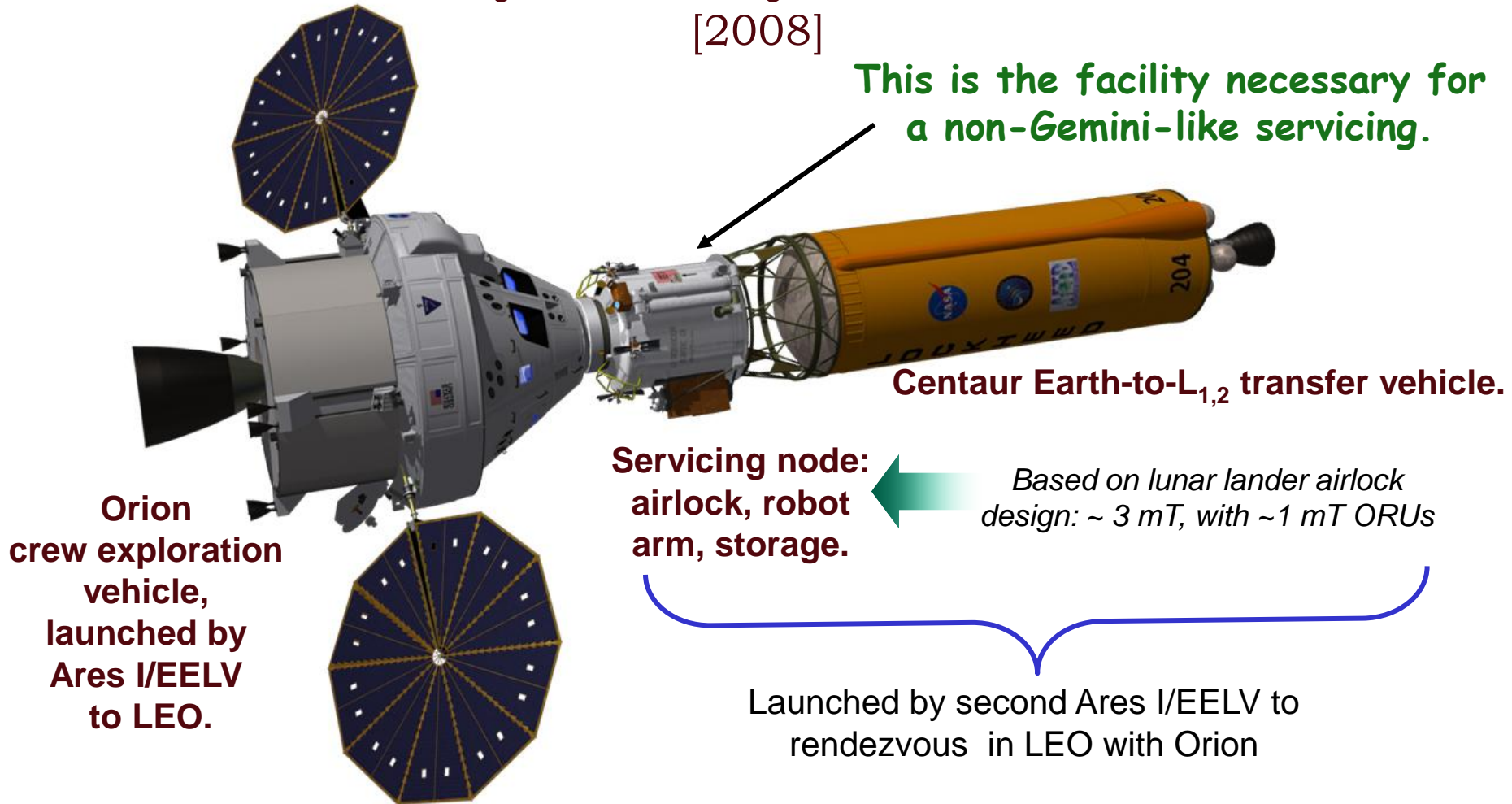


Concept of operations to use a pair of Ares I/EELV vehicles to carry astronauts to Earth-Moon $L_{1,2}$ “jobsites” within 10 years. [Thronson, Lester, Dissel, Folta, Stevens, & Budinoff (2008)]

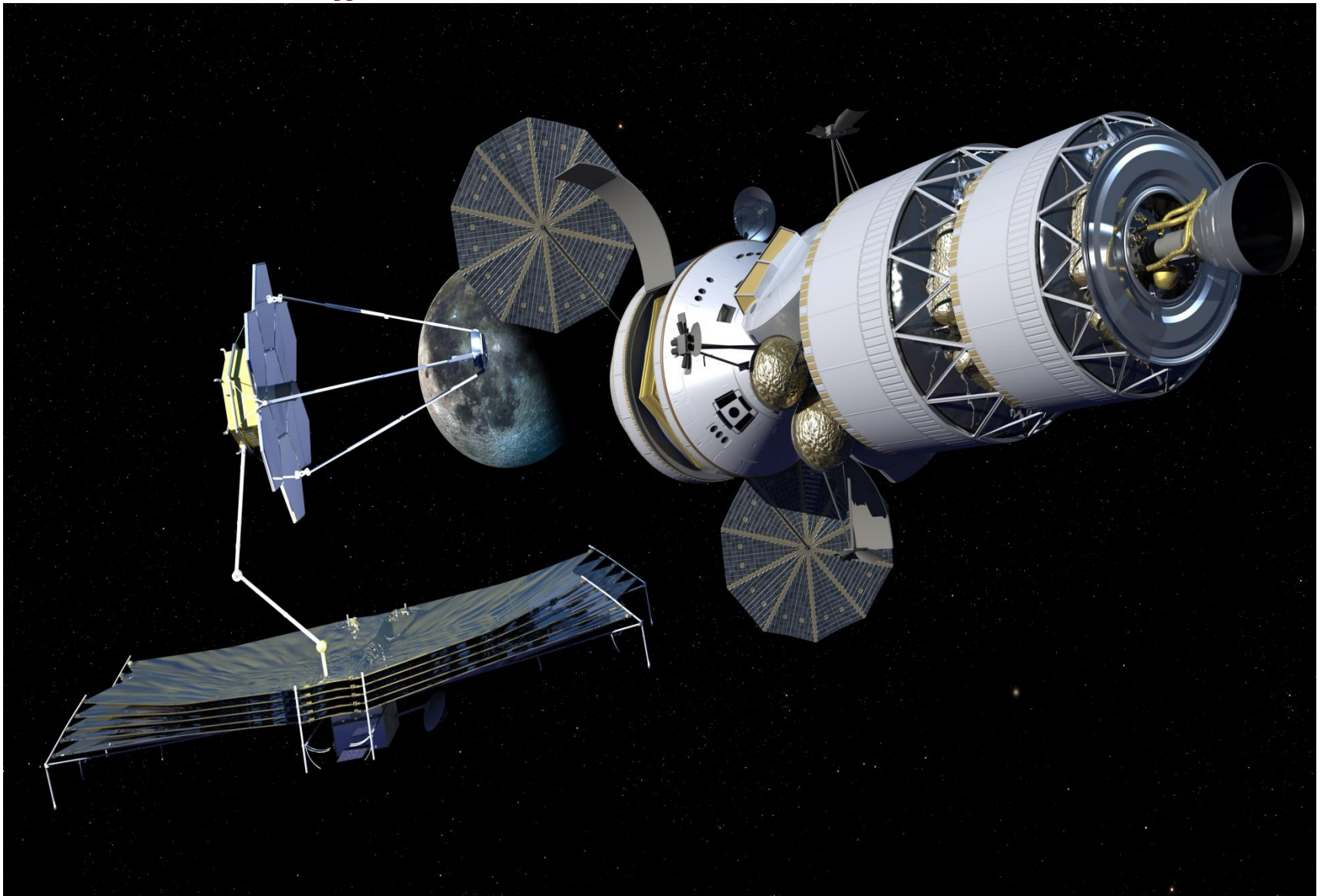
Minimum-Element Astronaut Servicing System Beyond LEO

[2008]

This is the facility necessary for
a non-Gemini-like servicing.

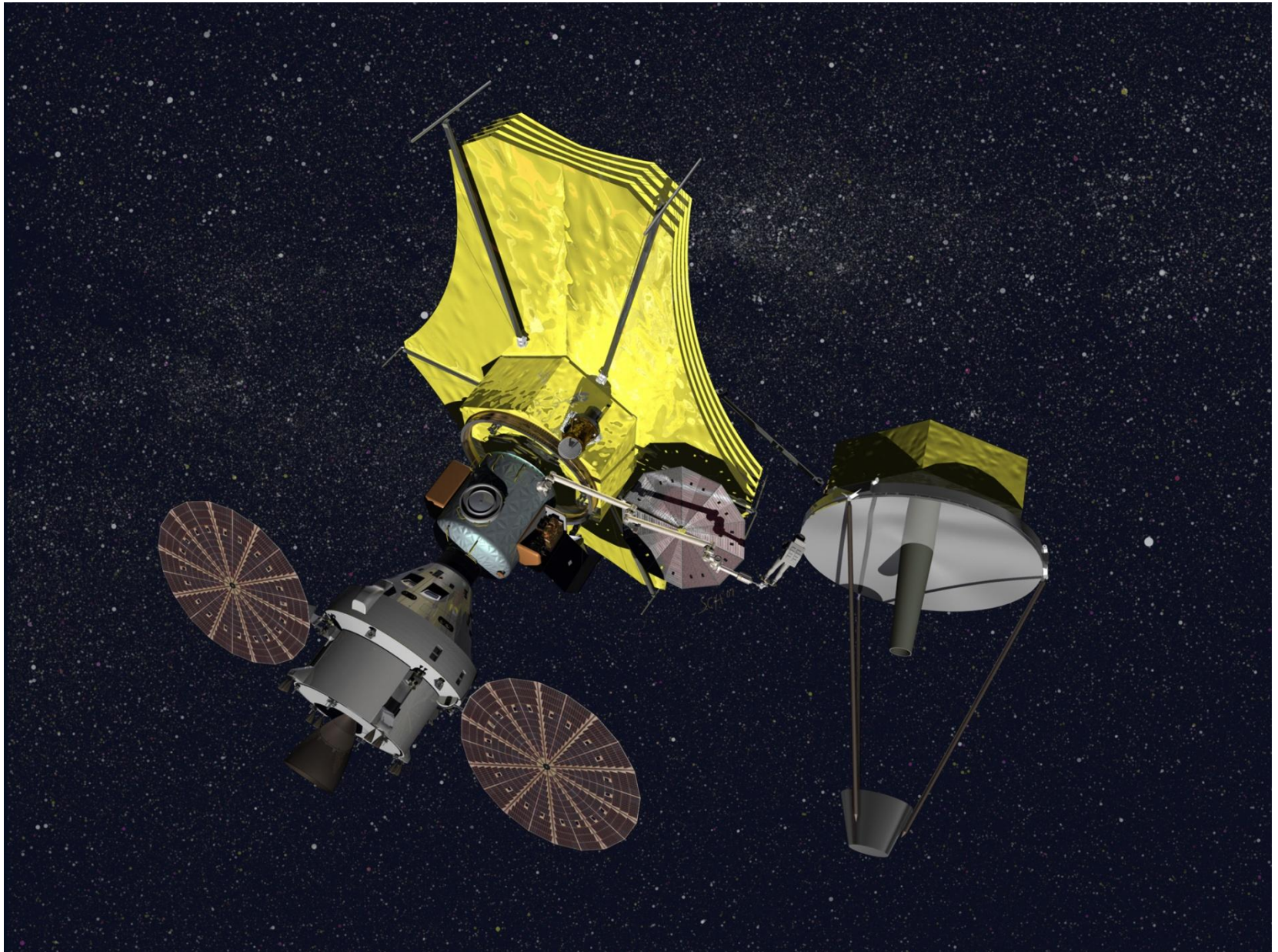


This Orion "stack" concept uses elements of the Constellation (or equivalent) architecture intended to be developed within a decade. It appears at present to use the minimum number of elements necessary for 2 - 3 week operations throughout cis-lunar space.



A cis-lunar "sortie" concept for servicing the ~10 m SAFIR observatory at an Earth-Moon $L_{1,2}$ venue using an augmented Orion and servicing module based on a lunar lander airlock system. [Source: *Future In-Space Operations (FISO) working group and JF&A*]

Orion/Servicing Node with Large Telescope at EM $L_{1,2}$



Transfer Point Architecture: Building on ISS Experience

The “Gateway”

Priority goals of science and human spaceflight as enabled by extended ISS operations with a human operations facility follow-on.

Understanding how to live and work productively in space:

The capabilities and experience being developed on the ISS, which are critical if humans are to live and work in space, will be lost without a prompt follow-on facility.

Extensive participation of an international partnership:

European and Russian ISS partners are committed to long-term operations on ISS and have already begun design studies for post-ISS astronaut in-space operations.

Human exploration of the lunar surface:

Astronaut/robot operations from an Earth-Moon libration-point “Gateway” permit sortie missions throughout the lunar surface, as well as on-orbit depoting capabilities to support extended surface operations.

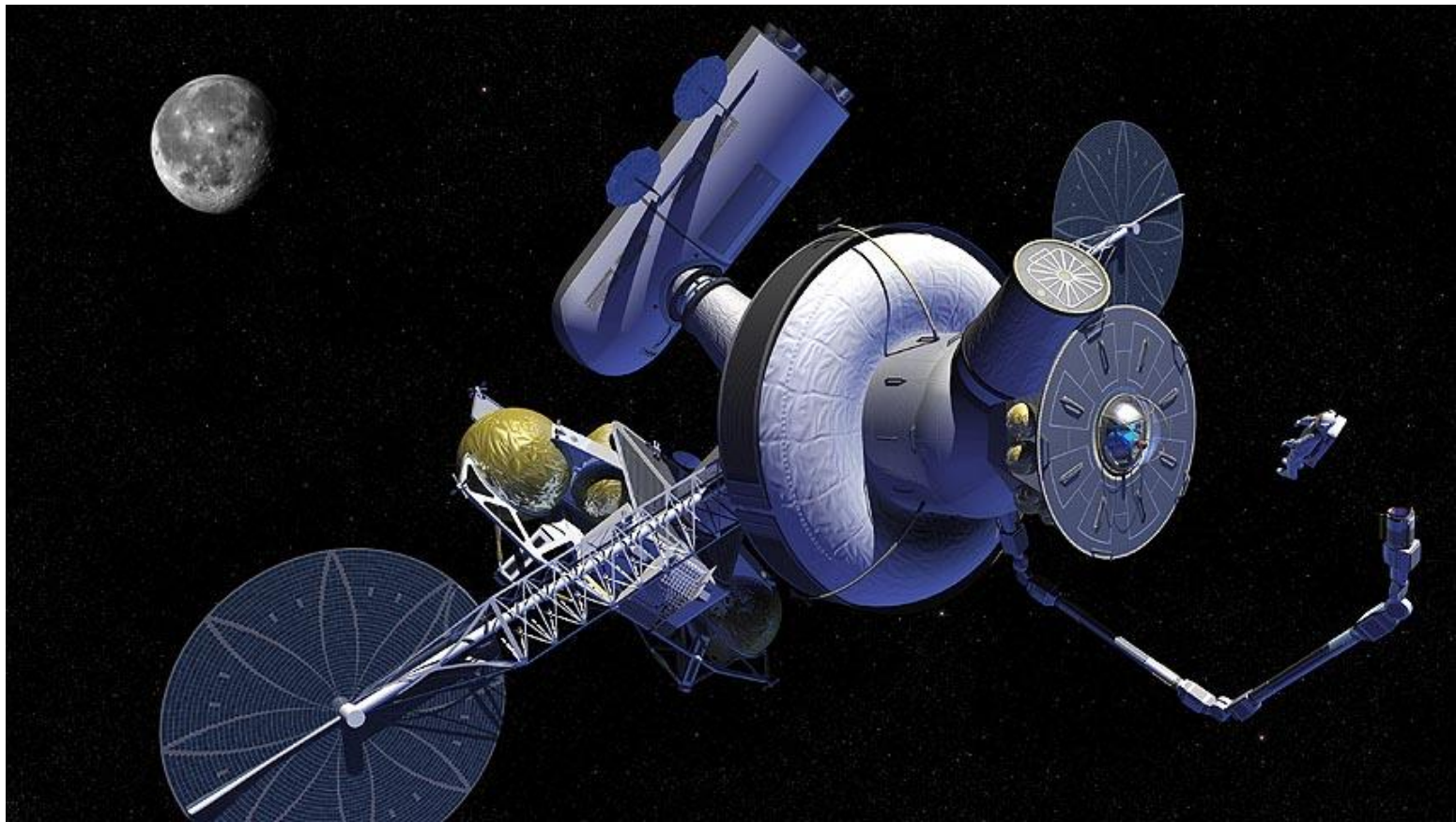
Preparation for long human voyages beyond the Earth-Moon system:

Very long-duration human voyages will require capabilities that will not be fully developed even after extending NASA participation in ISS. These capabilities will be developed via a post-ISS libration-point depot “Gateway.”

On-orbit upgrade and maintenance of complex science facilities:

The series of successful shuttle missions to HST has demonstrated the effectiveness and popularity of astronaut in-space upgrade and maintenance of a major science facility: a libration-point “Gateway” will continue this major capability.

Staging/Servicing/Depot Site at Earth-Moon $L_{1,2}$ [Inflatable habitat launched by heavy lift]



Block 1 (2005) concept for inflatable long-duration facility. A LEO-to-libration point transfer vehicle is shown at one of the three docking ports on the far side of the “Gateway,” next to a lunar lander. On the near side is the satellite upgrade, repair, and maintenance site. Major science facilities transfer from their observing sites to this location for upgrade.

[Concept from H. A. Thronson, the Future In-Space Operations (FISO) working group, and John Frassanito & Associates.]

Design Overview: Gateway (2005)

[Talay, Thronson, FISO working group, and JF&A]

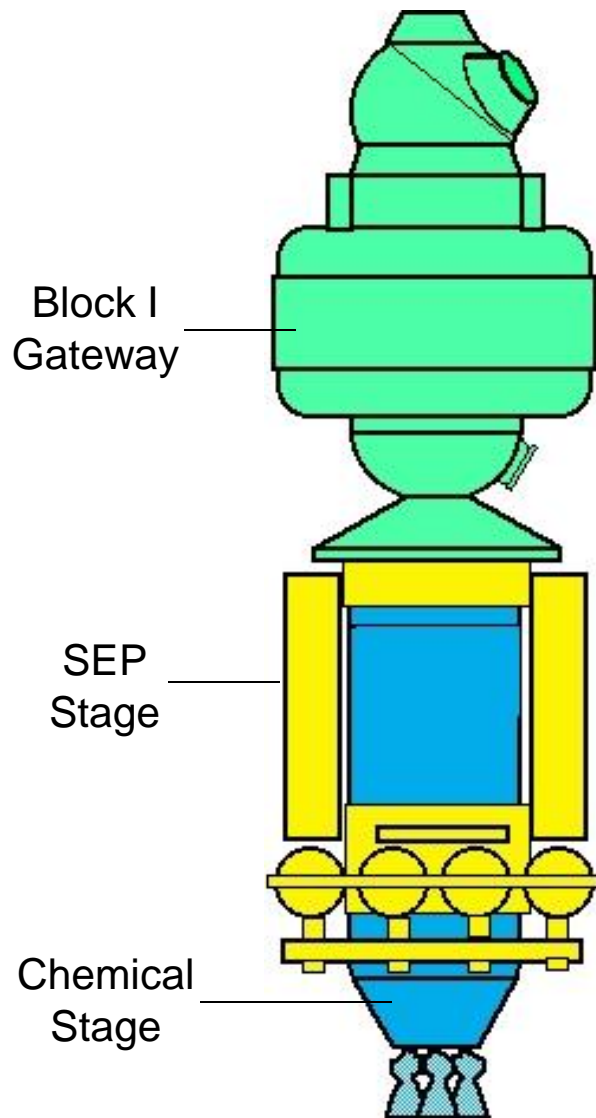
- Launched by 95 mT (to LEO) heavy lift
- SEP to $L_{1,2}$, then deploy hab volume
- Supports 4 crew (launched separately)
- 12.8 m maximum diameter after inflation
- 575 cu m hab volume (~ 60% of ISS complete volume)
- Radiation protection added & storm shelter in core structure.
- 3 docking ports on rotating turret



Gateway Element	kg
Power System	1542
Avionics	251
ECLSS	3768
Thermal Control System	894
Habitability & Human Factors	2507
EVA Systems	900
Vehicle support for EVA	212
EVA Transition Aids	123
EVA Tools	132
Airlock	433
Structure	12321
Inflatable skin	3270
Core structure	1678
Turret mechanisms	400
Interstage adapter	200
Docking adapters (3)	1996
EVA work platform	100
Work platform support struts (8)	264
ORU/Robot storage	150
Radiation protection	2000
Cupola	198
Secondary structure (20% of structure)	1815
Hard shell MMOD	250
Robotics	227
Attitude Control System	424
Propulsion (RCS)	235
Subtotal (Inert Mass only)	23320
25 % Margin (Inert System)	5870
Propellant (RCS)	1268
Crew, Provisions, Consumables	0
Total	30458

Design Overview (2005)

Overall Stack at LEO Injection



Overall mass: 95 mt

Gateway: 30.5 mt

SEP stage: 17.0 mt

LOX/LH2 stage: 47.5 mt

Overall length: 19.8 m

Overall diameter (max): 5.8 m

Main chemical propulsion (Ref: P&W):

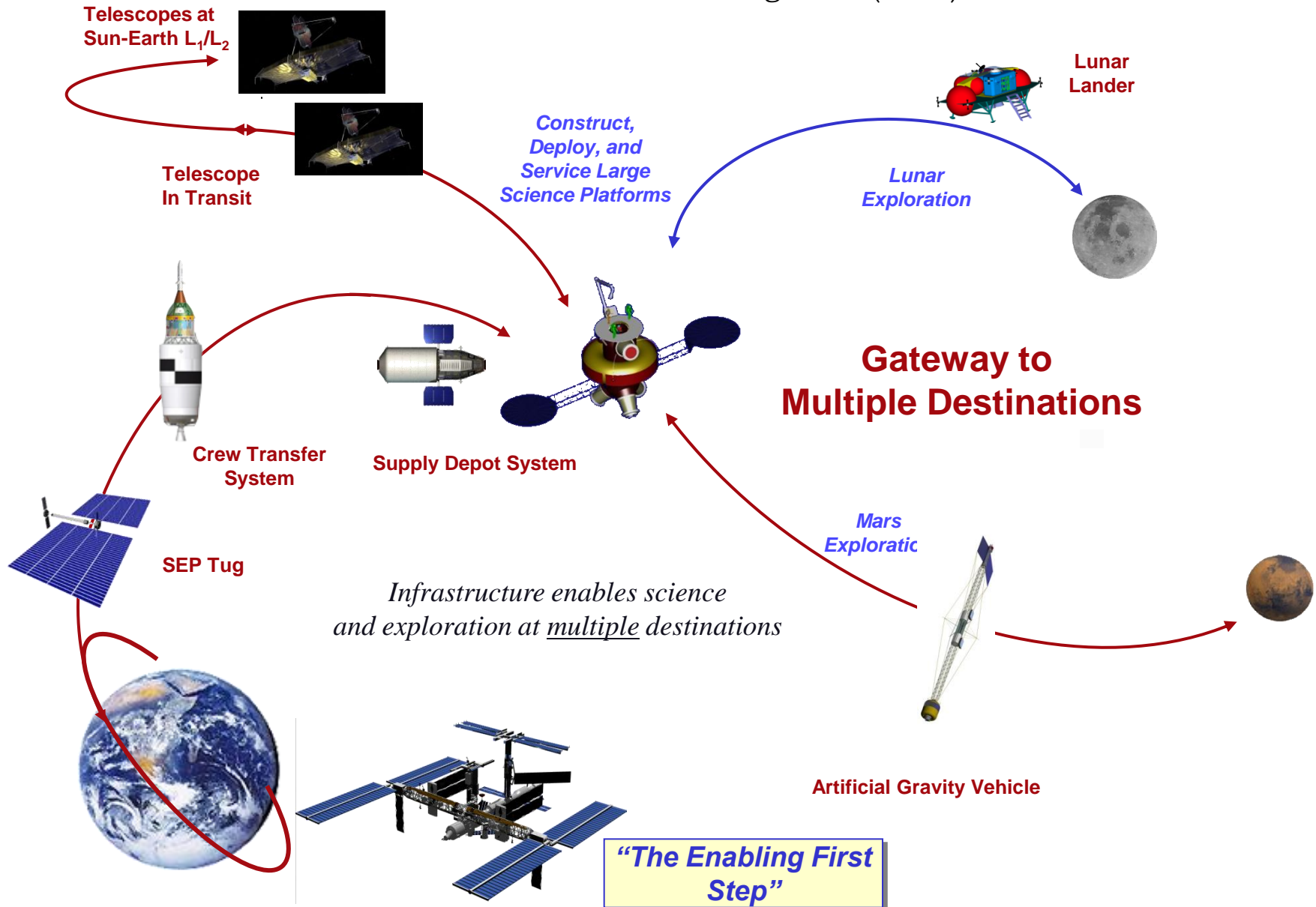
- 3 x RL-10 engines
- 25 Klbf
- LOX/LH2
- O/F=3.5
- Isp = 370 sec

Main SEP propulsion

- 6 Hall Effect 50 kW engines
- Cryo Xenon
- 3650 sq m PV arrays

“Gateway” Operations/Demonstration Architecture: Supporting Multiple Destinations at Libration Point Transfer Node

Source: NASA Decade Planning Team (2001)



SUMMARY

Plausible future human spaceflight hardware appears to be able to be adapted to carry astronauts into cis-lunar space for servicing, upgrade and other operations.

Future free-space operations, including servicing/assembly, build upon nearly two decades of ISS and HST construction and servicing. If humans are ever to travel beyond the Earth-Moon system, these capabilities will need to be developed and demonstrated.

- Expensive, complex optical systems in free space for astronomy and the Earth sciences: deploy, service, repair, upgrade, and rescue.
- Essential experience in advance of longer human voyages beyond the Earth-Moon system.
- Opportunities for in-space support for extensive lunar surface operations: comm relay, re-supply, depoting, contingency/emergency support.
- Astronaut capabilities augmented by new generations of robot systems that are already revolutionizing how humans operate in complex and challenging environments: OE, ATV, SUMO, HTV . . .

Ref: <http://futureinspaceoperations.com>

References:

Recent lunar/free-space concept studies: ESMD-RQ-0005 *Lunar Architecture Focused Trade Study Final Report* 04 February 2005

Concepts for future space operations: www.futureinspaceoperations.com

Decade Planning Team/NASA Exploration Team space operations designs: history.nasa.gov/DPT/DPT.htm

Review of use of libration points for scientific missions: International Astronautical Congress 2003, IAC-03-13.2.03

Design for dual-launch Orion servicing mission at libration points: International Astronautical Congress 2008, IAC-08-A5.3.6

Early design studies of libration point “Gateway”: International Astronautical Congress 2002, IAC-02-13.2.04

Strategies for servicing future large observatories: 2005 SPIE Conference 5899-21

Summary report on HST robotic servicing mission: AIAA Space 2007, Paper 6255